

DOCUMENT RESUME

ED 276 449

IR 051 663

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TITLE Operations Research Applied to Libraries and Information Centers.
PUB DATE 85
NOTE 18p.
PUB TYPE Viewpoints (120) -- Reports - Descriptive (141)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cost Effectiveness; *Information Centers; *Library Administration; *Management Systems; Models; *Operations Research; Planning; Problem Solving; Statistical Analysis; Systems Analysis

ABSTRACT

The greater organizational complexity of libraries and information centers in recent years has given rise to more complex problems for managers. To facilitate solutions, operations research (OR) techniques have been developed that consider the quantitative dimensions of problems along with their political and organizational aspects. Eight standard OR research techniques have been identified as the application of allocation, competition, inventory, queuing, replacement, routing, search, and sequencing problems to obtain the information needed in certain recurring situations. This paper focuses on benefit-cost analysis, a type of competition problem that is typically used to: (1) compare all the good effects (benefits) of a program with all the bad effects (costs and disbenefits) to judge whether it is better to implement or not to implement the program; (2) determine which of alternative versions of programs are best; and (3) decide what collection of programs or projects constitutes the best expenditure within a set, overall budget limit. Although most frequently used to decide capital investment programs, benefit-cost techniques may also be used for smaller programs, such as the retention of back periodical issues in a library with a strong emphasis on current information sources. Quantitative manipulations are often simple, and computers are used as aids in performing more complex calculations. Notes are provided. (KM)

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OPERATIONS RESEARCH APPLIED TO
LIBRARIES AND INFORMATION CENTERS

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IR051663

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ABSTRACT

Operations research techniques have been developing since the early 1940's. They focus on the solution of complex problems. They can be helpful to deal with problems in libraries and information centers arising from the greater organizational complexity in the 1980's. Benefit-cost analysis, an example of a competition problem, is considered and applied to a periodicals retention problem. Awareness of operations research techniques can benefit librarians and information center managers as more data on their operations become available as a by-product of computer applications.

INTRODUCTION

Three factors affecting the management of libraries and information centers in the 1980's are:

- the social, governmental and commercial organizations served have become more complex;
- the accumulation, storage and dissemination of knowledge and information have become more complex; and,
- staffs and services have become more sophisticated and often larger in scope.

Greater organizational complexity causes more complex problems for managers. Management techniques appropriate to the problems are required. Problems can often be more easily resolved if their quantitative dimensions are considered along with political and organizational aspects. Quantitative methods are available to apply to complex problems. Complex problems in many organizations have been studied and techniques developed to help resolve them. These techniques are grouped under the heading, operations research (OR) management. Greater awareness of operations research techniques by librarians and information center managers can help in the resolution of complex problems.

Operations research techniques highlight the key factors in a situation to facilitate decision making in solving problems. The emphasis of operations research is on the problem; that is, general circumstances are viewed as background to the problem and are considered only in-so-far as they affect the problem or are affected by its resolution.

Although operations research techniques are quantitative, a librarian or manager does not need a high level of mathematical training to apply them. A basic understanding of the logical concepts, and a faith that the formulas developed by mathematicians and operations research experts will work, are all that are needed to begin. Some experience in the application of simple operations research techniques develops the understanding and abilities of the manager. Management involves dealing with resources to get the best results in circumstances in which there are unknown factors. Operations research people use the word "uncertainty" to describe the unknown. Operations research techniques reduce uncertainty. They allow the manager to be more certain that the decision will get the best results with the least cost. It is more important to be able to use operations research to communicate and understand than to be able to work through to the solutions of complex problems.

By studying a problem, the concepts of operations research can be established. Once concepts are established in a managers thinking, an operations research expert can be employed for data manipulation and consultation on more complicated situations. This article presents the operations research technique of Benefit-cost analysis, explains the concepts involved, illustrates the technique, and reflects on its application in libraries. It is hoped this review will encourage readers to increase their capabilities of using quantitative methods to solve management problems. The uninitiated will (hopefully) see that there is nothing to fear in operations research methods. Novices will have an opportunity to grow. And, the experienced manager may learn a new insight on an old situation.

BACKGROUND

Developed during the Second World War as an aid to military decision making, operations research was subsequently used to improve industrial production

and in many other spheres of policy making. Operations research can be applied to both routine organization problems or used for strategic planning. It is an approach to problem solving that allows managers to make better decisions by providing a scientific basis for examining and evaluating operations. The official definition of the Operations Research Society of the United Kingdom describes Operations Research more precisely and succinctly:

Operational Research is the application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials, and money in industry, business, government, and defense. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcomes of alternative decisions, strategies, or controls. The purpose is to help management determine its policy and actions scientifically.¹

Over the years OR scientists noticed similarities among some problems they had to solve. Although no two situations were ever exactly alike, certain circumstances arose regularly enough to lead them to identify a body of "standard" operations research techniques. These groups include:

- Allocation problems are applied when available resources are not sufficient to complete all jobs to be done.
- Competition problems involve an outcome that depends in part on decisions made by people other than the decision maker.
- Inventory problems are to determine the amount and frequency of acquisition of resources.
- Queuing problems apply to providing facilities to service unscheduled arrivals.

- Replacement problems try to minimize the effect of worn out or consumed materials.
- Routing problems determine the best path through a network of activities.
- Search problems involve how to best seek information.
- Sequencing problems are those that order a set of tasks in a multistage process.

The technique considered in this paper, benefit-cost analysis, is a type of competition problem.

ELEMENTS OF OPERATIONS RESEARCH

Five elements of operations research techniques have been identified: decision variables, objective functions, parameters, constraints, and the model.

- Decision variables are the alternatives or major factors that are trying to be accomplished through the application of operations research techniques. They are often conditions that are desired to be reached.
- Objective functions are the criteria or measure of what is to be achieved. They are applied to the decision variables or the parameters. Objective functions are often costs in the form of dollars or time expended.
- Parameters are variables that are not under the control of the decision makers. These are external to the problem, but affect the circumstances in which the problem is defined.
- Constraints are limits placed on the decision variables; they establish boundary conditions for the model. They are either internal or external to the problem, but are made internal because they apply directly to the decision variables.

- The model is the way of putting the variables and parameters together with the functions. Models are categorized according to their characteristics. Two basic types of techniques can be used to achieve solutions: algorithms, which are calculations to get the best solutions, and heuristic techniques in which a best solution is not guaranteed.

BENEFIT-COST ANALYSIS

Before the mid-nineteen sixties about the only group regularly doing benefit-cost analysis was the U.S. Army Corps of Engineers. They were required to by the River and Harbor Act of 1902 and The Flood Control Act of 1936. The new stress placed on program accountability and assessment throughout the federal government in the mid-1960's caused benefit-cost analysis and other quantitative evaluation techniques to thrive.² Some librarians and information center managers saw the value of stating library programs in benefit-cost terms. They realized that arguments for increases (in facilities, budgets, or whatever) would be more valued by resource allocators if supported by factual analysis, rather than the traditional opinions of "experts."³ By understanding the value of information provided in benefit-cost analysis, librarians and information center managers can use this technique to gain more funds for their operations. Initial applications may be rudimentary, but as experience grows, so can the scope of applications. Benefit-cost analysis can become quite mathematical when dealing with discounting and internal rate of return, but technical expertise is usually available. The experts may be available within the parent organization of the library or information center.

Not all evaluations are benefit-cost analyses. But they are when they include the following:

- (1) comparing all the good effects (benefits) of a program with all the bad effects (costs and disbenefits) to judge whether it is better to implement or not to implement the program;
- (2) determining which of alternative versions of programs are best; and
- (3) deciding what collection of programs or projects constitutes the best expenditure within a set, overall budget limit.⁴

CONCEPTS

Benefit-cost analysis answers these questions:

- Should this program be funded? (Is it worth the cost?)
- Which program should be funded? (Which alternative is preferable?)

It is generally used to decide capital investment programs. The basic concept is that all benefits and all costs are given dollar values.

There are five elements in benefit-cost analysis.

- (1) Objectives--the desired changes intended to be produced.
- (2) Alternatives--possible competing uses of available resources.
- (3) Costs--budgeted costs of resources directly consumed as well as secondary costs. Disbenefits might qualify as secondary costs.
- (4) Model--the relationships among the characteristics of the alternatives and their impacts used to trace the anticipated costs and benefits of each alternative.
- (5) Criteria--bases on which the preferred alternative or alternatives will be determined.⁵

The basic procedure of benefit-cost analysis has four steps:

- (1) Identify alternative projects or programs that might be funded.
- (2) For each alternative, identify all benefits and costs and assign a dollar value to each.

- (3) Compute the present value for each cost land benefit. Because money over time can produce an increase in worth, a dollar in the future is worth less than a dollar today. Making future dollars equivalent in worth to present dollars is called discounting.
- (4) Compare alternatives by one or more of these methods.
 - (a) Net benefit, which is the present value of all benefits minus the present value of all costs. Choose the alternative with the highest net benefit.
 - (b) Benefit-cost (B/C) ratio, or the present value of all benefits divided by the present value of all costs. Choose the alternative with the greatest B/C ratio.
 - (c) Internal rate of return, which is the discount rate that makes the net present value of a project equal to zero. A project is economically justified if the internal rate of return is greater than the accepted discount rate.

Some problems arise in the application of benefit-cost analysis in the areas of identifying all benefits and choosing an appropriate discount rate, and the method (a, b, or c above) for choosing among the alternatives.

These criteria justify a project economically. In choice, among alternatives, the net benefit may be lower but the benefit-cost ratio higher for a smaller project compared to a larger project. A disadvantage of the benefit-cost ratio is that it is affected by the decisions on what are costs and what are disbenefits. Disbenefits are the loss of benefits by persons affected by a project, but who are not necessarily paying its costs. Net benefit does not have this same problem with cost and disbenefit decisions. Generally, to decide between mutually exclusive projects take the one with the highest net benefit, while to decide between projects that are not mutually exclusive use the benefit-cost ratio criterion.

EXAMPLE

Although benefit-cost analysis is generally used to decide on capital investment programs, some small programs have characteristics that fit the cost-benefit model. One such program is the retention of back periodical issues in a library with strong emphasis on current information sources. This emphasis is usually accompanied by a limited amount of space in which to store materials, so that there is a finite amount of shelf space available for periodicals. All library shelf space is equally valuable.

Other assumptions are that paper copies of the periodicals are stored in boxes on the shelves; that two levels of usage are evident from past records: high level and low level; and that microfilm copies are bought for all high usage periodicals. These copies are for security and back-up because the paper copies circulate and a significant number of missing issues result over time. The storage costs of microfilm are negligible, the purchase cost is absorbed by the budget, and a microfilm-to-paper copier is available through inter-library loan. Speed of retrieval is not a constraint for borrowed low usage periodicals or copied high usage ones.

Further, runs of old issues of all periodicals will be too worn and incomplete to benefit from their resale. Usage patterns of both high and low usage periodicals can be divided into five time periods of five years each: 1 to 5 years, 6 to 10 years, 11 to 15 years, 16 to 20 years, and 21 or more years. Usage during the first period (1 to 5 years) is heaviest. There is decreasing usage until the 20th year, after which usage is so light that it can be disregarded.

The objective of benefit-cost analysis is to determine the number of periods between the second and the fourth (6 to 10 years to 15 to 20 years) to retain periodical issues in each of the two usage levels. Although a few titles may vary from the general usage patterns, it is necessary to justify discard

decisions because of political pressure within the organization which the library serves.

The alternatives for the periodicals at the end of each time period are to either keep them or discard them. The alternatives do not apply to the first time period (1 to 5 years) because there is an automatic keep decision at that point. It is also of interest to discover if the discard alternative is to be chosen automatically at the end of the fourth period (16 to 20 years) or if another five year time period (21 to 25 years) should be added.

The costs to keep periodicals are the space which they require plus the use of boxes, both of which become available for reuse if the periodicals are discarded. On average, five years of one periodical requires one-half of one shelf and five boxes. One-half of one shelf is one-twentieth of a section of shelving. All values are in present dollars because pricing of both costs and benefits are current, not what actually was spent or will be spent for the periodicals.

The model is the benefit-cost ratio. A benefit-cost ratio of one or greater than one indicates a "keep" alternative decision, while a benefit/cost ratio of less than one indicates a "discard" alternative decision.

The criteria on which to base the choices of alternatives for each time period for each usage level of periodicals are the costs to shelve and box in contrast to the benefits of not needing to make photocopies of microfilm inhouse or borrow copies through inter-library loan.

PROCEDURE

The alternatives are to "keep" or to "discard" the high usage and the low usage periodicals at the end of time period two, three and four. Only the "keep" alternative need be analyzed because the "discard" alternative would have exactly inverse figures. Costs and benefits can be determined for each usage

level of periodical for each time period. When the benefit-cost ratio is greater than one or one, keep the periodicals at the end of that time period. When the benefit/cost ratio is less than one, discard the periodicals at the end of that time period.

The benefits identified for keeping periodicals are that copies would not need to be made from microfilm or borrowed through inter-library loan when an issue is requested. Issues are requested according to the following table, based on past records.

<u>Usage</u>	<u>Time Period</u>		
	<u>2nd</u>	<u>3rd</u>	<u>4th</u>
High	180	100	50
Low	50	30	10

The price of each copy made from microfilm averages \$2.00. The price of each copy borrowed through inter-library loan averages \$5.00. These prices include copy costs and staff time. Benefits for each usage level of periodical for each time period are as follows.

<u>Usage</u>	<u>Time Period</u>		
	<u>2nd</u>	<u>3rd</u>	<u>4th</u>
High	\$360.00	\$200.00	\$100.00
Low	\$250.00	\$150.00	\$ 50.00

The costs for keeping periodicals are that copies need to be kept orderly, a handling cost, and the costs of boxes and shelf space. Handling costs are as follows:

<u>Usage</u>	<u>Time Period</u>		
	<u>2nd</u>	<u>3rd</u>	<u>4th</u>
High	\$150.00	\$ 80.00	\$ 40.00
Low	\$ 60.00	\$ 35.00	\$ 15.00

Because each year of a periodical takes one box, which costs \$3.00, five years of a periodical (high or low usage) costs \$15.00 to box. A section of shelving costs \$60.00 and has ten shelves. Because each periodical (high or low usage) takes one-half shelf for five years the cost to shelve five years is one-twentieth of \$60.00, or \$3.00. Total storage cost for any periodical for any period is \$15.00 plus \$3.00, or \$18.00. It has been determined that the value of the building and utilities to keep one periodical for five years is \$100.00. Total costs for periodicals by level of usage and time period are as follows:

<u>Usage</u>	<u>Time Period</u>		
	<u>2nd</u>	<u>3rd</u>	<u>4th</u>
High	\$268.00	\$198.00	\$158.00
Low	\$178.00	\$153.00	\$133.00

To chose an alternative for each level of usage for each time period divide the benefits by the costs.

<u>Usage</u>	<u>Time Period</u>		
	<u>2nd</u>	<u>3rd</u>	<u>4th</u>
High	360/268	200/198	100/158
Low	250/178	150/153	50/133

The benefit-cost ratios are as follows:

<u>Usage</u>	<u>Time Period</u>		
	<u>2nd</u>	<u>3rd</u>	<u>4th</u>
High	1.34	1.01	0.63
Low	1.40	0.98	0.38

Therefore, the high usage periodicals would be kept through the end of the fourth time period, at which point they would be discarded. The low usage periodicals would be kept through the end of the third time period, at which point they would be discarded. There is no need to consider the addition of another five-year time period from 21 to 25 years. Further benefit-cost analyses could be performed on a year-by-year basis to precisely determine the discard year between the third and fourth time periods for high usage periodicals and between the second and third time periods for low usage periodicals.

CONCLUSIONS

Although the retention of periodicals might seem a simple decision to make, it can become an unresolvable problem if some basis for making the decision is not established. Often the seemingly obvious basis for a decision, minimal usage, is not reliable. For one thing, the shortage of space can make the establishment of any minimal usage above zero an unacceptable criterion. The question then becomes where that level should be set. To survey potential users is folly because they will always say "keep" the ones I am likely to use, but "discard" the ones someone else might use. Therefore, a consistent policy, with noteworthy exceptions, which allows the establishment of a uniform level of

usage is ideal. Benefit-cost analysis is a technique which makes such a policy possible.

We have seen that there are many techniques and methods available under the heading of Operations Research. The basic need in modern libraries and information centers is for managers to be able to apply appropriate techniques and methods in making better decisions. This paper illustrates that operations research techniques can help librarians and information managers make those decisions by applying quantitative methods.

Quantitative manipulations can be simple. If they become complex, there are experts in the field of operations research and sophisticated calculation equipment available. The computer has entered libraries as an aid, both to the retrieving bibliographical information and to record keeping for vast files of information. The computer's capacity and self-monitoring sub-systems also make it a source of operational statistics previously not available, or not easily gathered by, librarians.

The data gathered by computers as they are used to serve the functions of the library can be used to analyze those functions in ways previously not possible. If librarians and information managers are not aware of the power of operations research techniques available to them, then they will not be able to use the data made available by computers.

NOTES

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